Deconvolution for spectral data of LEDs

Balázs Kránicz[1] and Yoshi Ohno[2]
[1] University of Veszprém, Egyetem u. 10, Veszprém, Hungary
[2] National Institute of Standards and Technology, Gaithersburg, Maryland, USA

1. Regression of LEDs' spectra

Before starting the discussion about deconvolution a preliminary study is presented about nonlinear regression of LED spectra. This topic will be needed for computer simulation of spectral measurements.

In an investigation spectra of more than 60 different LEDs were measured with a CCD-type detector. The resolution of these measurements can be considered as 1 *nm.* Then a model function was found with which piecewise regression of LED spectra can be performed in such a way that u'-v' chromaticity differences between the original spectra and the regression functions are smaller than 0.0005 for almost all LEDs. Formula (1) shows the general model function and 6 pieces (i = 1,…, 6) of such a function were used for regression.

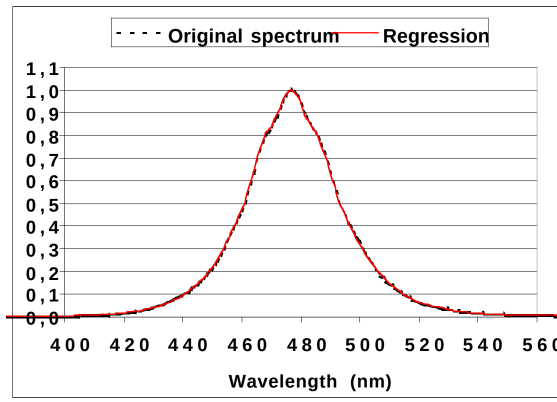

Figure 1

$$f_i(x) = a_i \cdot m_i^{-\frac{b_i}{1000}|x-c_i|^{p_i}} + d_i \qquad (1)$$

Figure 1 shows such a piecewise regression of the spectrum of a blue LED. The chromaticity difference in u'-v' is 0.000 071 in this case.

2 Computer simulation of spectral measurements

For a computer simulation the above described regression functions were used as if they would have been spectra of LEDs (*original spectra* in what follows). These *original spectra* were represented as tables with resolution of 0.1 nm.

For bandpass function of the simulated spectroradiometer ideal triangular functions belonging to different bandwidths ($\Delta\lambda$ = 1 nm; 5 nm; 10 nm and 20 nm) were chosen, also with 0.1 nm resolution. Applying convolution sums of the *original spectrum* and the appropriate bandpass function, spectral data for any bandwidth and step could have been calculated.

Spectral measurement data calculated in case of bandwidth and step $\Delta\lambda$ = 1 nm were defined as the *basic data set*, hence 1 nm resolution is generally sufficient for colorimetric calculations.

The problem how to reconstruct this *basic data set* knowing only spectral data belonging to larger bandwidths and steps can be solved by applying deconvolution as described in [1]. Here a brief description is presented about the essence of the procedure:

Let $S(\lambda)$ denote the *basic data set* where $\lambda \in \Lambda := \{380, 381, \ldots, 779, 780\}$. (The dimension of elements in Λ is nm, of course.) Let $\hat{S}(\lambda)$ denote the function approximating $S(\lambda)$ where $\lambda \in \Lambda$ also.

Let $M(\lambda, \Delta\lambda)$ denote a piece of spectral data simulated for wavelength λ with bandwidth $\Delta\lambda$. Here $\lambda \in \Gamma := \{380, 380 + \Delta\lambda, 380 + 2 \cdot \Delta\lambda, \ldots, 380 + n \cdot \Delta\lambda = 780\}$. Do not forget that in this case the resolution of the original spectrum and the bandpass function is 0.1 nm.

Let $\hat{M}(\lambda, \Delta\lambda)$ denote that value that can be calculated by a sum as a convolution of $\hat{S}(\lambda)$ and the appropriate triangular bandpass function belonging to $\Delta\lambda$. The resolution of $\hat{S}(\lambda)$ and this bandpass function is and should be 1 nm.

Then changing the values $\hat{S}(\lambda)$, where $\lambda \in \Lambda$, a cost function of the form

$$E(\hat{S}) = \sum_{\lambda \in \Gamma} \left(\hat{M}(\lambda, \Delta\lambda) - M(\lambda, \Delta\lambda)\right)^2 \tag{2}$$

should be minimized.

3. Results

In the following example "spectrum" shown in Figure 1 was used. The bandwidth and step were $\Delta\lambda$ = 10 nm. Figure 2 shows the *basic data set*, the spectral data (*Sampling* in the figure) and the function of a simple *Lagrange interpolation* of the spectral data. Values of this Lagrange interpolation function are initial values of $\hat{S}(\lambda)$, i.e. the initial point the numerical method was started from when minimizing $E(\hat{S})$. Although deconvolution could be performed in infinitely many different ways, if such an initial point is used as the starting point, the deconvolved result is going to remain quite smooth.

Figure 3 shows the effect of deconvolution applied in this case. Table 1 summarizes some results for different bandwidths.

Although this short draft paper deals only with one example, quite similar results are reached when applying deconvolution for spectral data taken from spectra of different LED types.

Reference

[1] John B. Shumaker, Deconvolution, Self-Study Manual on Optical Radiation Measurements, Chapter 8, Editor: Fred E. Nicodemus

Table 1. Summary of some results in case of "spectrum" shown in Figure 1.

Chromaticity values of the *basic data set*: u' = 0.1043; v' = 0.2752.

	$\Delta\lambda =$	**20 *nm***	**10 *nm***	**5 *nm***
Spectral data	$u' =$	0.1043	0.1043	0.1043
	$v' =$	0.2825	0.2771	0.2756
	$1000 \cdot \Delta_{u'v'} =$	7.2631	1.8736	0.4074
Simple Lagrange interpolation	$u' =$	0.1044	0.1044	0.1043
	$v' =$	0.2822	0.2769	0.2756
	$1000 \cdot \Delta_{u'v'} =$	6.9995	1.6467	0.4044
Deconvolved spectrum	$u' =$	0.1043	0.1043	0.1043
	$v' =$	0.2754	0.2752	0.2752
	$1000 \cdot \Delta_{u'v'} =$	0.1809	0.0033	0.0004

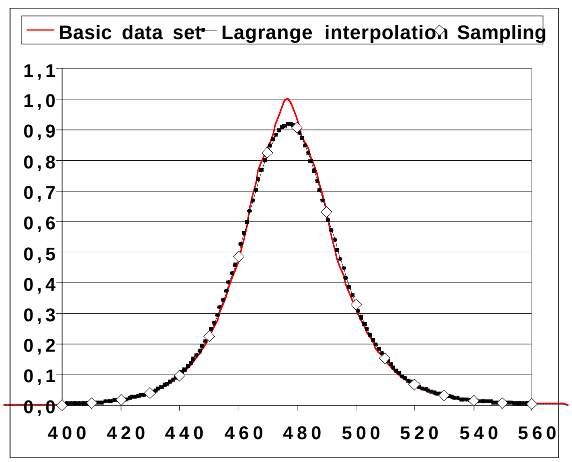

Figure 2

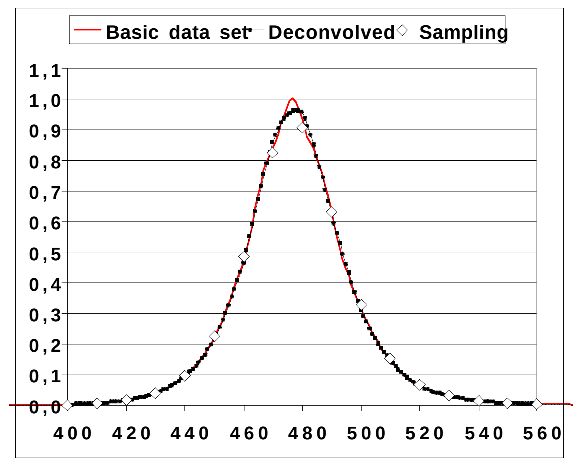

Figure 3